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Applying machine learning to global surface ocean and seabed data to reveal the controls on the distribution of deep-sea sediments

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World's ocean basins contain a rich and nearly continuous record of environmental fluctuations preserved as different types of deep-sea sediments. The sediments represent the largest carbon sink on Earth and its largest geological deposit. Knowing the controls on the distribution of these sediments is essential for understanding the history of ocean-climate dynamics, including changes in sea-level and ocean circulation, as well as biological perturbations. Indeed, the bulk of deep-sea sediments comprises the remains of planktonic organisms that originate in the photic zone of the global ocean implying a strong connection between the seafloor and the sea surface. Machine-learning techniques are perfectly suited to unravelling these controls as they are able to handle large sets of spatial data and they often outperform traditional spatial analysis approaches. Using a support vector machine algorithm we recently created the first digital map of seafloor lithologies (Dutkiewicz et al., 2015) based on 14,400 surface samples. This map reveals significant deviations in distribution of deep-sea lithologies from hitherto hand-drawn maps based on far fewer data points. It also allows us to explore quantitatively, for the first time, the relationship between oceanographic parameters at the sea surface and lithologies on the seafloor. We subsequently coupled this global point sample dataset of 14,400 seafloor lithologies to bathymetry and oceanographic grids (sea-surface temperature, salinity, dissolved oxygen and dissolved inorganic nutrients) and applied a probabilistic Gaussian process classifier in an exhaustive combinatorial fashion (Dutkiewicz et al., 2016). We focused on five major lithologies (calcareous sediment, diatom ooze, radiolarian ooze, clay and lithogenous sediment) and used a computationally intensive five-fold cross-validation, withholding 20% of the data at each iteration, to assess the predictive performance of the machine learning method. We find that the occurrence of five major lithologies in the world's ocean can be predicted on the basis of just two or three parameters, notably sea-surface salinity and sea-surface temperature. These parameters control the growth and composition of plankton and specific salinities and temperatures are also associated with the influx of non-aerosol terrigenous material into the ocean. Bathymetry is an important parameter for discriminating the occurrence of calcareous sediment, clay and coarse lithogenous sediment from each other but it is not important for biosiliceous oozes. Consequently, radiolarian and diatom oozes are poor indicators of palaeo-depth. Contrary to widely held view, we find that calcareous and siliceous oozes are not linked to high surface productivity. Our analysis shows that small shifts in surface ocean conditions significantly affect the lithology of modern seafloor sediments on a global scale and that these relationships need to be incorporated into interpretations of the geological record of ocean basins.

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